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105/CA1621.
VHF ADMITTANCE
BRIDGE
TYPE B901.

WAYNE KERR

105/CA 1621

MP MASTER

MA24518

V.H.F. Admittance Bridge

B901

Instruction Manual

Serial No. 388

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GENERAL

The B901 is an Admittance Bridge intended primarily for measurements on unbalanced aerials and feeders in the frequency range of 50 to 250 Mc/s. It is suitable also for the measurement of component values and receiver input admittance, provided that suitable precautions are taken in the connections to the bridge.

It is fitted with a coaxial outlet to which any one of three types of plug and socket can be attached by means of adaptors. All three adaptors are supplied with the instrument. They are for use with G.E.C. Type 3, PL259 (Amphenol 83-1SP) and BNC plugs respectively.

The conductance dials are direct-reading, the internal standard consisting of three drums of miniature high-stability resistors. Susceptance is obtained from the reading of a known equivalent capacitance and frequency, the standard being a non-inductive variable capacitor calibrated in picofarads positive or negative about a zero point.

The instrument is 9" wide x $8\frac{1}{2}$" high x $7\frac{1}{2}$" deep (23 x 21·5 x 19 cm) and weighs approximately 12 lb (5·4 kg).

PERFORMANCE

SUSCEPTANCE: The range of susceptance is equivalent to ± 75 pF and the accuracy of measurement is

± 2 per cent, ± 0·5 pF up to 200 Mc/s and
± 5 per cent, ± 0·5 pF from 200 to 250 Mc/s.

When negative capacitances are measured, reference should be made to the error curves (facing page 13).

CONDUCTANCE: The range of measurement covers 0-100 millimhos in three ranges: 0-90 mmho in 10-mmho steps; 0-9 mmho in 1-mmho steps; 0-0·9 mmho in 0·1-mmho steps. The accuracy of measurement is as follows:

0- 50 mmhos:	± 2 per cent ± 0·1 mmho up to 200 Mc/s
	± 5 per cent ± 0·1 mmho from 200 to 250 Mc/s
50-100 mmhos:	± 5 per cent up to 200 Mc/s
	±10 per cent from 200 to 250 Mc/s.

Connection is made to the resistors by short plungers, and the leads are so arranged that the series inductance is a minimum. The stray capacitance caused by the leads is balanced by an equivalent capacitance in the "unknown" arm of the bridge. The value of this equivalent capacitance is adjusted to bring the bridge to balance with the connection to the unknown open-circuited and the variable capacitor half-engaged. In this way it is possible to measure both positive and negative susceptances without resetting. The bridge will, however, require re-balancing when the frequency is changed.

PRINCIPLE OF OPERATION

The B901 bridge employs the tapped transformer principle, which is described fully in Wayne Kerr Monograph No. 1, available on request.

In the particular application of the general principle to this bridge, a transformer having a secondary winding of four turns tapped at one turn is connected to the voltage source. The windings are so arranged that the voltage ratio is effectively equal to the turns ratio over the whole frequency range, and the voltage across the known admittance is three times that across the unknown (see circuit diagram).

When the bridge is balanced, the currents in the known and unknown arms are equal, and the value of the unknown admittance is therefore three times that of the standard admittance. The use of a 3:1 ratio in this way enables smaller standard components to be used, with a consequent reduction of parasitic elements.

CONNECTION TO UNKNOWN ADMITTANCE

The unknown admittance is connected between an earth plate mounted on the top of the bridge and a small brass contact boss let into the earth plate and insulated from it by a polythene bush. The contact is drilled and tapped 4 B.A.

The earth plate is drilled and tapped 6 B.A. with three holes equally spaced on a pitch circle of 1•2" diameter.

The bridge can be adapted to take a cable connector by screwing a short rod into the contact and a skirted tube to the plate.

It is important to remember that the bridge measures the admittance in the plane of the top of the top plate of the bridge. If a cable of appreciable length separates the unknown from the plate it will be necessary to transfer the admittance of the unknown to the plane of the top plate by using the modified transmission line equations given in section 2 of 'Measurement Procedure'.

When measuring components that cannot be connected to the bridge by a length of line of known characteristics, allowance should be made for the series inductance of the connections and the parasitic capacitances from the body of the unknown to the earth plate of the bridge.

SETTING UP THE BRIDGE

Any conventional signal-generator with an output of 100mV can be used as a source. The bridge input admittance varies both with frequency and with the admittance of the unknown, and there is consequently a tendency to pull the source off frequency as the bridge is balanced. If a narrow-band receiver is used for a detector it may be necessary to reset the frequency of the generator as the balance point is reached.

A high-sensitivity receiver is required for the detector, and its input circuit must be well screened.

With a source providing 100mV, a receiver with a sensitivity of 20μV at 50 Mc/s and 2μV at 250 Mc/s is required for a discrimination of 0·1 mmho.

Most communications receivers will be found suitable, without alteration, but it may be necessary to cut out the A.G.C. circuit or fit a meter to find the balance point.

OPERATING THE BRIDGE

1 Set the source and detector to the frequency of measurement, and the main bridge dials to zero.

2 With the unknown disconnected, balance the bridge by means of the two "Set Zero" controls.

3 Connect the unknown and re-balance the bridge for a null on the detector, using the main dials.

The conductance dials are direct-reading and independent of frequency. Susceptance is found from the known equivalent capacitance and the frequency.

CONNECTING CABLE

When using a connecting cable between the unknown and the bridge, it is important that a perfectly coaxial connection be made to the bridge. An adaptor with a characteristic impedance equivalent to that of the cable should be used. The bridge should be balanced without the adaptor fitted, as its capacitance will effectively disappear when the terminated cable is connected.

SCREENING

Unless the screening of the source and detector is extremely good, errors in measurement will be caused by direct radiation, particularly between the unknown and the input to the receiver. Any signal so radiated will be picked up by the receiver and will effectively be balanced by an equal anti-phase signal from the bridge when balanced. The bridge will therefore be off balance at the null point by an amount equal to the radiated signal. As it is sometimes difficult to screen the unknown adequately, particular care should be taken with the input to the detector.

The amount of radiation can be checked by withdrawing the plug connecting the receiver to the bridge and turning it so that the inner contact is screened while the outer makes contact with the outer contact of the socket. This breaks the receiver circuit but leaves the screening of the cables intact. Under these conditions the signal picked up should be negligible when the receiver is set at maximum gain.

SOURCES OF ERROR IN MEASUREMENT

1 INTERNAL MOVEMENT

The bridge is robust but is not proof against rough handling or dropping. The silver tapes which connect the transformer to the standard and unknown may become displaced in position as a result of severe mechanical shock and introduce an error which will be greatest at the higher frequencies.

2 COMPONENTS

The resistors are selected and adjusted to have an error not greater than 1 per cent at 10 mmho and above. Variation in resistance value between 0 and 250 Mc/s is in all cases less than 1 per cent and, apart from distributed capacitance and series inductance, the thickness of the cracked carbon film is less than the penetration depth at the highest frequency.

The greatest error is liable to occur at 250 Mc/s with ϕ equal to 45°, but precise measurement in this condition can rarely be required. Small conductances and large susceptances (series inductance beginning to take effect) will have increased error at this frequency.

3 DISCONTINUITY

The capacitance due to the field above the plate coaxial contact has been calculated to be 0·34 pF. When a connection is made to the Bridge this capacitance disappears or is modified.

4 COAXIAL CONTACT TERMINAL

Connexion is made to the unknown admittance from the transformer through a concentric line 0·25" long having Z_o = 16·2 ohms.

If a perfectly resistive termination of 16·2 ohms is made to the bridge terminal, the capacitance of the contact boss effectively disappears, leaving the bridge unbalanced to the extent of -1·5 pF.

The greater the difference from this value of resistance the smaller the error. A pure resistance of 30 ohms would give -0·4 pF error, and a resistance of 50 ohms only -0·15 pF.

5 USE OF STANDARDS

The sources of error due to internal displacement of the leads and changes in components (items 1 and 2 in the preceding section) can be checked by the use of external standard components.

A range of suitable standards (type Q561) has been developed by Wayne Kerr Laboratories, and these are available to special order.

MEASUREMENT PROCEDURE

1 CABLE CONNECTION

If a length of coaxial cable is used to connect an impedance to the bridge, it is necessary that the characteristics (electrical length and characteristic impedance) of the cable be known. If the characteristics are not given, they can be found directly by measurement of the short-circuit and open-circuit impedance of the cable.

It should be noted that, when the open-circuit test is being made, the capacitance due to the field above the top plate is transferred to the free end of the cable and altered in magnitude.

If the open-circuit reactance of the cable is C' pF and the short-circuit inductive reactance is C_L pF, then the characteristic impedance and electrical length of the cable are given by:

$$Z_o = 10^6/(2\pi f \sqrt{C_L C'})$$ where f is in Mc/s and C' is in pF

and

$$\tan \beta l = 10^6/(2\pi f Z_o C_L)$$ where $\beta = \frac{2\pi}{\lambda}$.

If βl is greater than 90°, $\tan \beta l$ becomes negative.

2 IMPEDANCES

Knowing Z_o and βl, the admittance $G_r + j\omega C_r$ at the end of the cable can be calculated from measurement of the admittance $G_e + j\omega C_e$ at the bridge connection, using the following equations:

$$G_r = \frac{G_e(1 + \tan^2\beta l)}{[1 + (C_e/C') \tan \beta l]^2 + G_e^2 Z_o^2 \tan^2 \beta l}$$

$$C_r = \frac{(C_e - C') [1 + (C_e/C') \tan^2 \beta l] + G_e^2 Z_o^2 C'}{[1 + (C_e/C') \tan^2 \beta l]^2 + G_e^2 Z_o^2 \tan^2 \beta l}$$

Conversely, if the admittance at the end of the cable is known, or is a standard, the admittance measured at the bridge connection is given by the following equations:

$$G_e = \frac{G_r(1 + \tan^2 \beta l)}{[1-(C_r/C') \tan^2 \beta l]^2 + G_r^2 \tan^2 \beta l \, Z_o^2}$$

$$C_e = \frac{(C_r + C') [1-(C_r/C') \tan^2 \beta l] - G_r^2 Z_o^2 C'}{[1-(C_r/C') \tan^2 \beta l]^2 + G_r^2 \tan^2 \beta l \, Z_o^2}$$

where G_e = Conductance at bridge end of line

C_e = Susceptance at bridge end of line

G_r = Conductance of termination

C_r = Susceptance of termination

β = $\sqrt{\epsilon} \cdot 2\pi/\lambda_o$ [$\pi = 180^\circ$]

(ϵ = dielectric constant of line

λ_o = wavelength in free space)

l = Length of line in metres

C' = $\frac{\tan \beta l \times 10^6}{2\pi f Z_o}$ pF, when f is in Mc/s.

This measurement enables the accuracy of the bridge to be checked.

CONVERSION OF PARALLEL TO SERIES COMBINATION

The admittances measured by the bridge are the effective parallel combinations at the end of the cable. To derive the equivalent series components C_s and G_s, the following equations can be used:

$$G_s = \frac{G_p^2 + \omega^2 C_p^2}{G_p}$$

$$C_s = C_p + \frac{G_p^2}{\omega^2 C_p}$$

Where

G_s = Series Conductance

C_s = Series Susceptance

G_p = Parallel Conductance

C_p = Parallel Susceptance

ADAPTORS

The three adaptors are suitable for connection to the following types of plug:

1 Adaptor CWP 3054

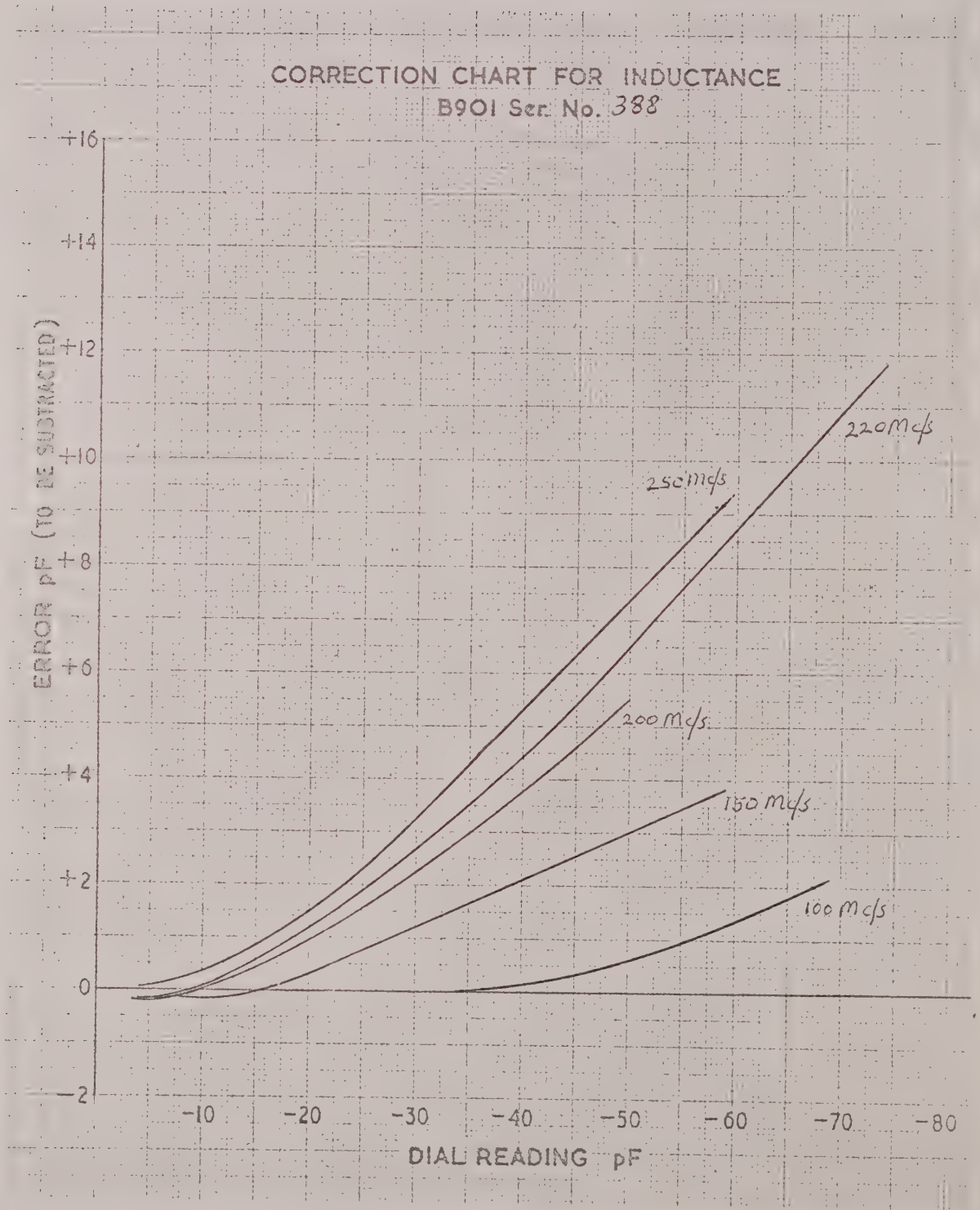
G.E.C. (Pirelli) Type 3
A.M. Type 605,Ref.No. 10H/4702
A.M. Type 586,Ref.No. 10H/4297.

2 Adaptor CWP 3058

Amphenol 83-1SP
American Military No. PL259
Greenpar Code No. GE 40001
Films and Equipment PL259.

3 Adaptor D 6166

BNC (Amphenol Series 31)
BNC (Belling-Lee Series L1331)


CORRECTION CHART FOR INDUCTANCE
B901 Ser. No. 388
+16
+14
+12
+10
+8
+6
+4
+2
0
−2
ERROR pF (TO BE SUBTRACTED)
250 m/s
220 m/s
200 m/s
150 m/s
100 m/s
−10
−20
−30
−40
−50
−60
−70
−80
DIAL READING pF

NEGATIVE CAPACITANCE CORRECTIONS

The accompanying graph shows the error which occurs when negative capacitances are measured. The curves show the error plotted against dial readings for various frequencies in the range covered.

To obtain the true value of a negative capacitance, first balance the bridge in the usual manner. From the dial reading and a knowledge of the measurement frequency, the corresponding error can be read from the curves (interpolating when necessary). This error must be subtracted from the dial reading.

Example:

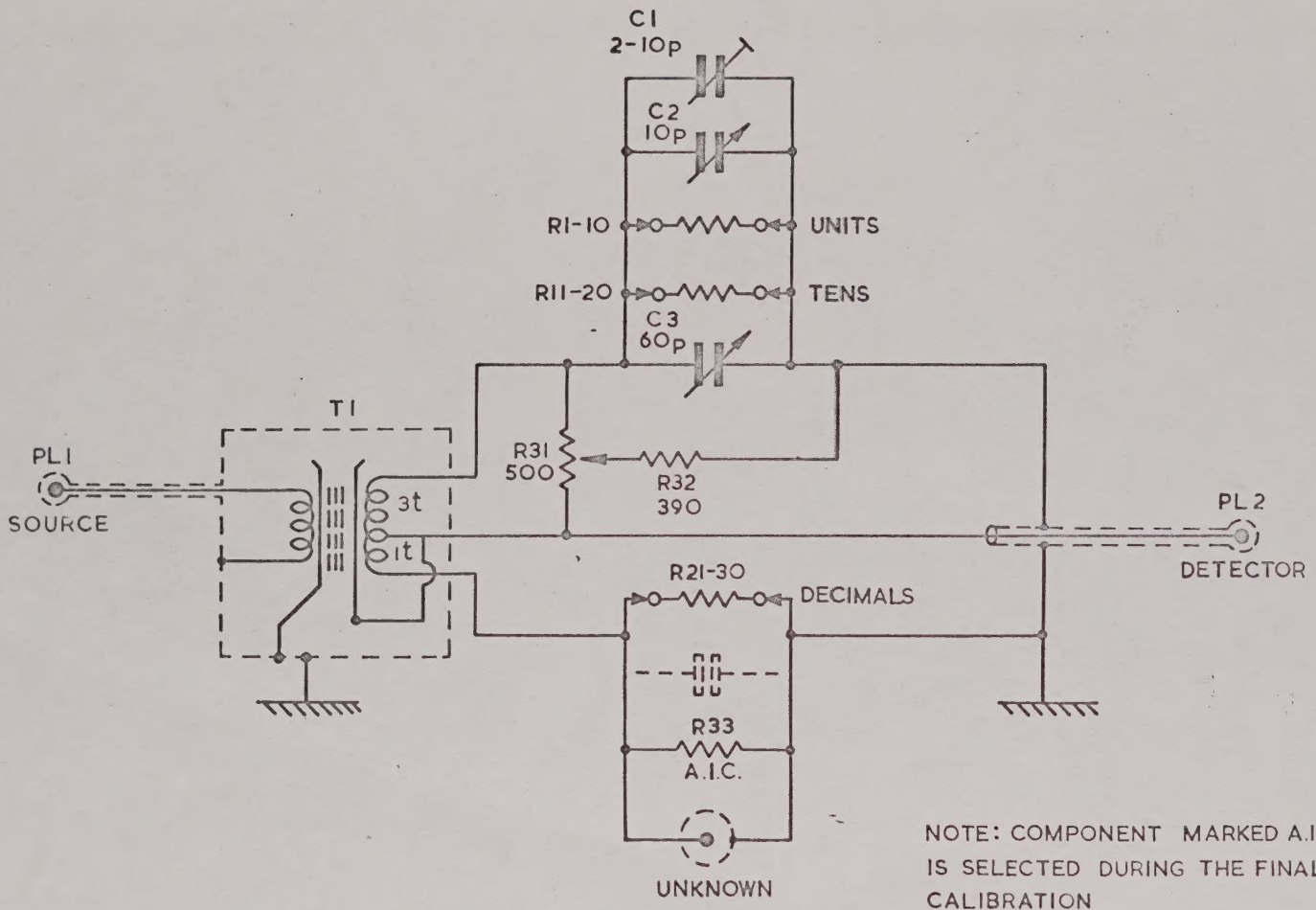
An inductive line, measured at 200 Mc/s, gives a negative capacitance reading of -29·5 pF. From the curve for 200 Mc/s, the error corresponding to -29·5 pF is seen (for one particular Bridge) to be +4·25 pF. The true value of negative capacitance is therefore -29·5-(+4·25)pF

= -33·75pF.

Such a correction is not required when positive capacitances are measured.

COMPONENT LIST

C1	10pF	Air-spaced Trimmer
C2	10pF	Air-spaced Variable
C3	60pF	Internal Standard, WK DRG. No. CNP3111
R1	"Dummy" Resistor (open circuit)	
R2	3,000Ω	± 3 per cent 1/8W High-Stability Carbon.
R3	1,500Ω	" " " "
R4	1,000Ω	" " " "
R5	750Ω	+ 2 per cent "
R6	600Ω	- 3 per cent "
R7	500Ω	+ 1 per cent "
R8	430Ω	- 2 per cent "
R9	375Ω	+ 0 per cent "
R10	333Ω	- 2 per cent "
R11	"Dummy" Resistor (open circuit)	
R12	300Ω	
R13	150Ω	
R14	100Ω	
R15	75Ω	+ 0 per cent
R16	60Ω	- 2 per cent 1/8W High-Stability Carbon.
R17	50Ω	
R18	42·8 Ω	
R19	37·5 Ω	
R20	33·3 Ω	
R21	1,000Ω	± 3 per cent 1/8W High-Stability Carbon
R22	1,110Ω	" " " "
R23	1,250Ω	+ 3 per cent "
		- 5 per cent "
R24	1,429Ω	± 5 per cent "
R25	1,667Ω	
R26	2,000Ω	+10 per cent "
		- 7 per cent
R27	2,500Ω	+15 per cent "
R28	3,333Ω	-10 per cent "
R29	5,000Ω	+20 per cent "
R30	10,000Ω	-10 per cent "
R31	500Ω	±20 per cent Carbon, Linear 1/4W.
R32	390Ω	±10 per cent 1/8W High-Stability Carbon.
R33	180Ω	± 1 per cent "
T1	Input Transformer	



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